The Role of Communication in the Reduction of Human Error

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MRM Research Program[1]
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SUMMARY

The first generation Maintenance Resource Management programs were based on Cockpit Resource Management training. These early programs, dating from 1989 through 1994, were intended to change skills and knowledge about interpersonal behavior and open communication in order to reduce errors through teamwork. They were successful in improving safety awareness and communication, which in turn led to safety improvements. These first generation programs were either intentionally limited to two days of training (Taylor & Robertson, 1995) or were brought to a premature end for extraneous reasons (Taylor, et al., 1997).

A single example of the second generation of MRM programs began in 1992. It was based on communication through the use of focus groups of foremen and mechanics and sought to directly address communicating and understanding maintenance errors. That approach led to on-shift meetings and mechanics' participation in planning technical changes that improved safety. This second generation of MRM was also limited in scope (Taylor, 1994).

The third generations of MRM programs essentially consisted of training programs to increase individual mechanic's safety awareness and to improve individual coping skills in dealing with safety issues. Research shows that in programs with two days of training, increased awareness results in trends toward fewer injury and ground damage incidents. Significant increase in the quality or quantity of communication does not typically occur as a result of this third MRM generation. It is usually a one-shot program, without follow-up. That (together with its emphasis on individual coping skills) seems to place participants in the position of not knowing whether or how much the MRM program is working, or whether other people value the lessons of the training like they themselves do. As such, these third generation programs have been observed to exhaust their inertial influence within a limited time (Taylor, 1998b).

One adaptation to the third generation of MRM has been to divide two days of training over several months. This may offer several advantages over the one-shot training model. First, it provides the opportunity for program facilitators to follow-up and elaborate the lessons from the first session. Second, the subsequent session begins to demonstrate management's commitment to an ongoing MRM program. Third, it may

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satisfy participants' desire for recurrent training. Initial evaluation results presented below appear to show that safety trends improve as a result of the MRM program and these trends continue after the second training day.

A fourth generation of MRM programs is now taking hold. It is characterized by a commitment to long term communication and behavioral change in maintenance (Patankar & Taylor, 1999; Taylor & Patankar, in press). Now, at the beginning of the 21st Century, the emergence of MRM should be seen as more than mere "awareness training," or coping skills for individual mechanics – it is the conscious process of increasing trust among maintainers, their managers, and their regulators that enable them to learn from present behaviors in order to improve future quality and efficiency. It is a process of cultural change.

INTRODUCTION

More than a decade ago the aviation maintenance community was startled to discover the importance of the "human factor" in safety – not merely in the design of jobs and tools, but in the aspects of interpersonal behavior and the management of people.

Starting in 1989, airlines in the U.S. began to address open communication to improve safety. Now, ten years after embarking on a journey to learn from these and subsequent communication programs in aviation maintenance we can now step back and review the larger implications of this movement. This is an overview of trends and results observed during that time.

MRM Definition

In the past seven years Maintenance Resource Management, or "MRM," has become one of the pillars in aviation human factors. The industry creators of a multiparty cooperative program in maintenance to improve communication and reduce errors (reported in Taylor & Christensen, 1998, pp. 48, 105-6) coined the term in 1992. The industry correctly defines MRM as "…an *interactive* [emphasis added] process focused upon improving the opportunity for the maintenance technician to perform work more safely and effectively" (ATA, 1999). In that same ATA document MRM is referred to as a training program, but MRM is much more than training. MRM is a tool to provide individuals and groups with the skills and processes to manage errors that are within their control, such as communication, decision-making, situational awareness, workload management, and team building. Part of MRM is training, but part of it must be the application and management of the attitude, skills, and knowledge that training and behavior can provide.

Before there was MRM, there was CRM for maintenance. And that was largely a training intervention. The earliest attempt to introduce the importance of interpersonal awareness and communication skills was not called MRM (Taggart, 1990) and it was not long lived, but through the enthusiastic response with which it was received by its maintenance participants it revealed a strong interest in this approach. It proved to be an idea in good currency.

The MRM Evaluation Research Program

With the visible success of Cockpit Resource Management (CRM) in flight operations during the decade of the 1980's, the first two airlines intentionally improving

communication in maintenance (Taggart, 1990; Fotos, 1991) each modeled their maintenance efforts after CRM programs within their company's flight operations. Naturally the creators of these pioneering maintenance programs drew heavily on the available research and hands-on experience from CRM. That included proven evaluation tools (Gregorich, et al., 1990) and successful training programs (Helmreich, et al., 1986) which were lightly modified and quickly applied to the initial maintenance communication program (Taylor, Robertson, Peck & Stelly, 1993).

Measurement development of attitudes related to MRM topics, of opinions about certain parts of maintenance operations, of intentions to use knowledge obtained from MRM, as well as of self-reports of subsequent behaviors -- which began in 1989 (Taggart, 1990) -- has continued and expanded (Taylor, in press). A data base of over 10,000 mechanics, maintenance managers, and other maintenance personnel from some dozen aircarriers and repair stations is now available at Santa Clara University and is used to compare city and company results against standardized scores.

The evolution of locally developed maintenance communication programs has progressed through three generations and is entering a fourth. The four generations of MRM have been, or currently are, being measured and evaluated. The results of these evaluations will be described below, together with an assessment of communication improvement -- and where available -- safety benefits.

FOUR GENERATIONS OF MRM AND SUSTAINED SUCCESS

In the paper to follow, four generations or steps in the evolution of MRM will be discussed. Each generation will be illustrated by at least one airline maintenance case of an MRM-type program. With the exception of case #1 all data reported here have been subjects of our ongoing MRM Research Program. All cases are numbered in the order presented and case numbering does not start over with each generation. The following characteristics will be described for each case, where available:

- Purpose and objectives or instructional topics of the program
- Reported likelihood of voluntary change resulting from the program
- Attitude and opinion changes resulting from the program
- Specific intentions to change as a result of the program
- Behavior changes resulting from the program, self-reported or observed
- Changes in safety performance

Generation 1: CRM-based Training in Communication Skills and Awareness.

Case 1.

The very first reported CRM program for maintenance in a large U.S. airline began in November 1989.

Program purpose. The purpose of the maintenance CRM training was similar to that of the company's flight crew CRM training -- to ensure that teamwork and coordination are optimal and best use is made of all resources, including people, information, and equipment (Taggart, 1990). The training topics were:

- Interpersonal communication

- Assertion and conflict
- Stress
- Critique skills
- Value of briefings
- Situation awareness
- Leadership behavior
- Case studies

The program was conducted for small groups over a several weeks and finally included over 80 maintenance managers and supervisors. Although it was intended that all 750 in maintenance management in the company would be trained, the program was suspended and the company was liquidated before that occurred. But as the first experience, that program set high standards.

Likelihood of voluntary change. Participant enthusiasm for the course was very high – over 80% said there would be at least a moderate change in their on-the-job behavior.

Case 2: Assertive management communication skills and performance.

Beginning in June 1991 a second airline company undertook a CRM in maintenance training course for communication and safety (Fotos, 1991). This training continued for over two years. This early and highly successful version of MRM emphasized open and assertive communication, both in theory and in practice, as well as an awareness of others. The detailed results of the evaluation study having been published in previous papers will not be repeated here, and bibliographic citations will direct the reader to the appropriate references

Program purpose. The purpose of the course was stated as "equipping participants with the skill to use all resources to improve safety and efficiency." Specific objectives, or topics covered were:

- Diagnose organizational "norms" and their effect on safety
- Promote assertive behavior
- Understand individual leadership styles
- Understand and manage stress
- Enhance rational problem solving and decision making skills
- Enhance interpersonal skills

Time was taken during the two-day training program to role-play giving and receiving assertive communication (Stelly & Taylor, 1992), and participants praised that activity highly (Taylor & Robertson, 1995, p.49). All maintenance management and professional engineering staff (N>2,000) attended the program.

Likelihood of voluntary change. Enthusiasm for this program actually exceeded the high marks earlier reported by Taggart (1990) – at the end of the two-day training nearly 90% of the participants said there would be at least a moderate change in their on-the-job behavior (Taylor & Robertson, 1995, p.15).

This program was brought to completion by August 1993 (a 26-month period).

Attitude changes. The post-training attitudes showed improvement in feelings toward participation, stress management, and communication; but no immediate improvement in attitudes about assertiveness – those would come later. These maintenance managers also initially indicated intentions to change in rather passive ways (e.g., "to be a better listener") than to immediately practice assertiveness and "speaking-up." Two months following training however, feelings about assertiveness increased for many of these managers – and their intentions for further steps were more active as well (Robertson, et al., 1995; Taylor & Robertson, 1995; Taylor & Christensen, 1998).

Performance changes. For 24 months following the onset of the program, the incidence of lost time injuries and aircraft ground damage decreased (Taylor & Robertson, 1995), and the former was highly correlated with the improvement in attitudes toward assertiveness just noted (Taylor, 1995).

In August 1993, upon completing the training for maintenance management and achieving these improvements in attitude and safety, plans were laid to move the program into the ranks of mechanics. Other concerns interfered with the continued progress of MRM and eventually only a small proportion of mechanics were trained. By that time top management's concerns had turned from communication and safety to station closures and cost cutting, and the excellent results of their MRM program began to reverse (Taylor & Christensen, 1998, pp. 128-129).

Case 3: Assertive AMT communication skills and performance.

Program purpose. Before the above reversal began in earnest, the MRM program was modified for mechanics by changing only the case studies to maintenance-caused accidents or incidents and leaving the purpose, the timing, the major topics and the exercises in place.

Beginning in September 1993 about 450 participants (one-third new supervisors and two-thirds mechanics) from 28 work units attended MRM training. By June 1994, after a period of just over six months, the pace for this training had declined to a trickle – mainly as a result of top management succession and changes in maintenance priorities.

Little, if any, of this type of intervention with mechanics (hereafter called Aviation Maintenance Technicians, or AMTs) and other operational hourly personnel had been previously attempted in North America. Common wisdom held that communication training for AMTs and other hourly workers was an unnecessary expense in a period of prolonged financial hardship -- and, in any event, that this kind of interpersonal training would probably benefit management participants more than hourly employees. Recurrent training for AMTs was typically limited to passively viewing videos produced by the company's Technical Training Department, or to on the job training (OJT) by lead or senior mechanics. Given those assumptions, the results of this MRM training were surprising.

Likelihood of voluntary changes. Like the management results in cases 1 and 2, the 300 AMTs show clear enthusiasm. Eighty percent (80%) of them reported that they expected moderate to large changes in their behavior as a result of the MRM training (Taylor, et al., 1997).

Specific intentions to change. These AMTs were also asked to write their responses to the question: "How will you use this training on your job?" Content coding of those answers resulted in the bulk of the responses divided into five categories: "Dealing better with others," "Being more assertive," "Being more aware of other's behavior," "Being a better listener," and "Fighting complacency/being more careful at work." The first two categories were classified as "active communication" intentions—to be carried out with coworkers, while the latter three were consider to be more passive coping behaviors — and could be done alone. Forty percent of the AMTs responses were coded in the first two (active) categories while some 45% were coded in one of the three passive categories. This proportional division would prove to be very high for active communication. The AMTs' positive experience with MRM training leads to enhanced performance as well.

Attitude changes. AMT attitudes immediately following the training reveal a marked change toward accepting command responsibility and an increased appreciation of stress management. In the main these results obtained for technicians parallel those reported for maintenance managers and support professionals (Taylor, 1995; Taylor & Robertson, 1995).

Performance changes. In part the AMT data proved even stronger than the management results in showing positive effects of collaboration and human factors training (Taylor et al., 1997). In particular, stronger relationships between AMT post-training attitudes and safety performance in the six months immediately following training is evidence of the fact that because AMTs are the persons directly effecting performance, their attitudes should most quickly relate to that performance. That brief program proved to be a successful venture into MRM training for AMTs. It is unfortunate that it was halted so soon after it began.

Generation 2: Directly Address Communicating and Understanding Maintenance Errors.

Case 4: Using Focus Groups to Reduce Errors in Aviation Maintenance.

During 1992-1994, the Quality Assurance (QA) department in another large airline (employing nearly 2,000 AMTs and foremen in 37 line stations) began an informal cooperative arrangement with the trade union (IAM) representing its AMTs, and with its FAA Flight Standards District Office (FSDO).

Program purpose. This cooperation was intended to reduce a high incidence of errors in maintenance documentation by opening communication channels among the company, the union and the regulator.

The program lasted two years and covered three phases. It began with 30 group interviews, involving over 150 AMTs and foremen in eight line maintenance stations. These interviews focused on maintenance paperwork errors, their causes, and their solutions. In the second phase of the project, the results from the interviews in the first phase were fed back to all parties and management took action based on the proposed solutions. In some cases the solutions/changes affected all of the company's line stations, and in other cases the changes were tried in one station (a "natural experiment") and reviewed against suitable comparisons. In the third phase, the changes were given time (up to 28 months after the onset of the MRM program) to affect measured error rates in maintenance documentation, and the results were distributed to all parties.

One of the solutions recommended and implemented involved passive engagement (e.g., formal training in paperwork for all line AMTs). The effects of that paperwork training on error rates was immediate, but short-lived (Taylor, 1995, Taylor & Christensen, 1998).

Two other solutions required active involvement and communication (e.g., pre-shift team meetings in order to open communication channels, and AMT group participation in re-designing the aircraft logbook form).

The two active communication solutions were implemented in one line maintenance station – one that had previously participated in the focus group interviews. Four months after their initial MRM focus group session, the station's employees were invited to join in a new activity. First, that station's foremen received training in communication and leading meetings, and they began holding daily crew briefings. Second, the AMTs had the opportunity to attend occasional, informal sessions to discuss ways to improve the aircraft logbook document layout. The logbook improvement sessions were led by a manager from the company's Quality Assurance department. The total paperwork error rates for this experimental station were matched with those of another line station of similar size and location that did not participate in the focus group interviews or in the crew meetings or logbook improvement effort. The main differences between the experimental and comparison stations were their reputations for morale and their relations with flight crews. During 1992-93, the morale and service reputation of the experimental station was considered poor, while the comparison station enjoyed a better image.

Performance changes. In May 1993, two months after the focus group interviews in the experimental station (but before any feedback to that station), its logbook errors were higher than either the comparison station or all stations combined. When the experiment began in August 1993, the experimental station subsequently experienced rapid and visible improvements attributed to the enhanced communication while the comparison station's error performance more closely matched the system overall (Taylor, 1995). For March through August 1994, nine to twelve months following the onset of the study, the experimental station continued to show a lower error rate than the comparison station and/or all stations combined. Thus, after the MRM interventions began there, the experimental station displayed a lower logbook error rate in both comparisons for every subsequent month available thereafter (Taylor, 1994; Taylor, 1995).

By 1995 the experiment concluded, not by plan, but by lack of momentum – the local managers and supervisors who supported the shift briefings and AMT participation in decision making left the station and/or the company. Their successors were encouraged to support another (and department-wide) program in non-safety related employee communication and participation. The QA, IAM, and FSDO partners to this company's cooperative MRM relationship continued their efforts to reduce errors. In 1993, these three partners created an on-going human-centered error investigation process which was designed to analyze specific cases of maintainer mistakes using a participative process and to apply what is learned to system-wide solutions (Marx, 1998).

In general, such second-generation programs, although participative, are reactive to past problems. Thus they are in part focused on the past.

Generation 3: Maintenance Training for Individual Awareness and Readiness.

In 1994 the curriculum for a different kind of maintenance training program was developed and distributed through Transport Canada. The program, called Human Performance in Maintenance (HPIM) is based on a two-day training course designed specifically for AMTs. It soon became widely known because of the maintenance-oriented nature of its training materials and its ready availability. Among HPIM's most popular innovations is a set of safety posters -- the "Dirty Dozen" posters – one for each of twelve major causes of maintenance errors (Taylor & Christensen, 1998, pp. 145-6). As evidence for the strength of HPIM influence, all reported MRM programs implemented in North America since 1994 have included the "dirty dozen" as a core set of concepts. The purpose of HPIM training as described in the prototype participants' workbook is "to create an awareness of the human aspect of aircraft maintenance and develop safeguards to lessen the "human cause" factors in maintenance."

In several ways HPIM has had a direct impact on the development of the third generation of MRM programs. First is the emphasis on "awareness." The HPIM purpose differs from the purpose of the CRM-based maintenance training in cases 1 through 3 above. HPIM focuses on awareness and coping mechanisms or safeguards, while the MRM of cases 1 through 3 focuses on skills such as assertiveness. Second is the emphasis on the individual. The objectives of the initial 1994 HPIM course emphasizes three of the dirty dozen – lack of communication, stress, and fatigue – two of which are primarily personal issues that can be best managed by the individual. Third is the emphasis on internal and passive change rather than interpersonal and active change. In HPIM both its curriculum and workbook illustrate this. The workbook includes a section on communication that emphasizes listening (passive rather than active communication) as the major technique. This trend that MRM was taking on an "awareness training" orientation has been noted by others (Kanki, et al., 1997).

Although the several cases of third generation MRM described below differ in significant detail from one another they all share a training purpose focused on awareness as well as resulting overwhelmingly in intended and reported changes which are passive, individual, coping adaptations rather than active changes in communication.

Case 5: AMT Awareness Leads to Improved Performance.

In 1996 a large airline undertook to provide MRM training for all of its AMTs.

Program purpose. The purpose of the program, stated in participant's workbook is to create an awareness of the impact of human performance on maintenance-related errors and personal safety. The learning objectives for the course were as follows:

- Relate how AMT characteristics and personal behavior can impact the maintenance process
- Identify 12 performance factors ["dirty dozen"] and their role in the chain of events leading to maintenance-related errors
- Develop personal techniques to minimize risk and maximize performance
- Give and receive feedback with coworkers related to personal safety

The company has trained over six thousand employees during a two and a half year period. It addressed its MRM training exclusively to AMTs (supervisors and managers account for less than 1% of the total trained in that company). The AMT's union and the company's management cooperated to initiate the training. Training materials were adapted from the HPIM package and the company standardized them for its own use -- including the use of local case illustrations. In addition to the three of the dirty dozen emphasized in the HPIM syllabus a fourth "dirty" item, "complacency," was added to the core curriculum. Training then continued at the local level with facilitators coming from the ranks of both AMTs and their first-line supervisors. This group of facilitators represented excellent use of local operations experience and leadership abilities. The training was coordinated and supported by the company's training and education department.

Likelihood of voluntary change. Enthusiasm was positive immediately following the training even if some participants hedged a little on their interpretation of substantial change. Over sixty percent of the participants said there would be a moderate or large change in their on-the-job behavior (Taylor & Christensen, 1998). Although a clear majority believes that the training will affect their actual behavior, this level of enthusiasm does not approach the high ratings -- between 80% and 90% -- reported for the earlier three MRM cases.

Specific intentions to change. These AMTs also responded to the question: "How will you use this training on your job?" Content coding of those answers resulted in the bulk of the responses divided into several categories including "Interacting with others," Being more assertive," Being more aware of other's behavior," "Being a better listener," and "Fighting complacency/being more careful at work." The first two categories -- "active communication" intentions -- can be compared with the more passive coping behaviors that can be done alone. As shown in tables 1 below, 27% of the AMTs' responses were coded in the active category while nearly 46% were coded in the passive category. This result is substantially lower for active communication than the AMT sample described in Case 3. This tendency toward passive coping behaviors is consistent with the purpose and objectives of the program.

Table 1

Case 5 Post-training Behavior Intentions (n=4613)

Total Passive Intentions	45.9%
Total Active Intentions	27.3%
Other	21.5%
No Change Intended	5.3%
	100%

Attitude changes. Statistically significant improvements were found in attitudes about sharing responsibility, communication, and stress management immediately following the training sessions. The change in the value of stress management was particularly striking. Furthermore, those same three attitudes remained stable for months

after the training. Attitudes toward assertiveness did not improve as a result of the training (Taylor & Christensen, 1998, pp. 154-155).

Performance changes. The AMTs' positive attitudes following MRM training leads to enhanced performance as well. In particular, the marked increase in appreciation of stress management two months after training showed the strongest correlations with low rates of injury and aircraft damage (Taylor, 1998a). Stress management is primarily a passive coping activity and its improvement following the training and its relationship to safety performance improvements is entirely consistent with this company's MRM purpose. In 1998, the performance trends for 1995 through 1997 for this case were promising (Taylor, 1998b), but at least for base maintenance AMTs who hadn't yet completed their MRM training, more time would be necessary to observe performance over a longer period (Taylor, 1998a).

Figures 1, 2, and 3 below show performance data for the expanded five-year period 1995-1999. All figures show linear trend lines (obtained using the method of "Least Squares") for the "before," "during" and "after-training" periods superimposed over the actual monthly data points.

Figures 1 and 2 show the trends "before, during, and after" MRM training for occupational injuries and aircraft ground damage for line maintenance performance. Figure 3 shows similar trends for occupational injuries for base maintenance.

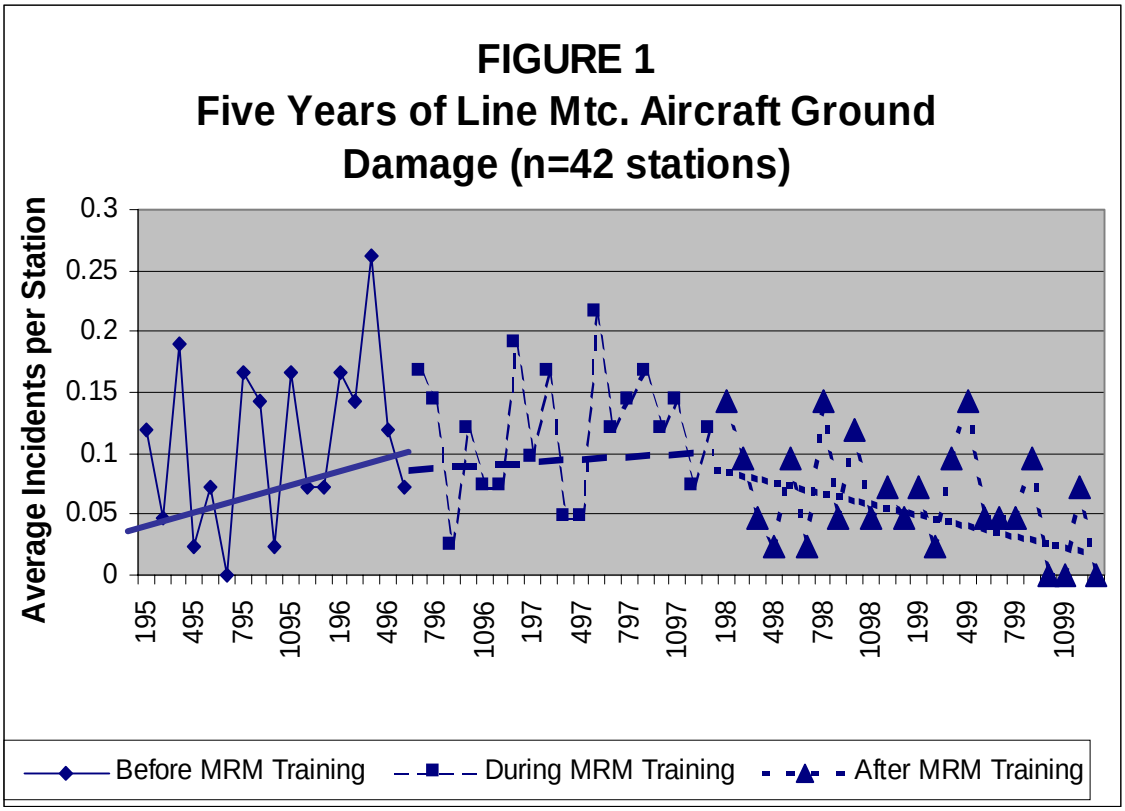
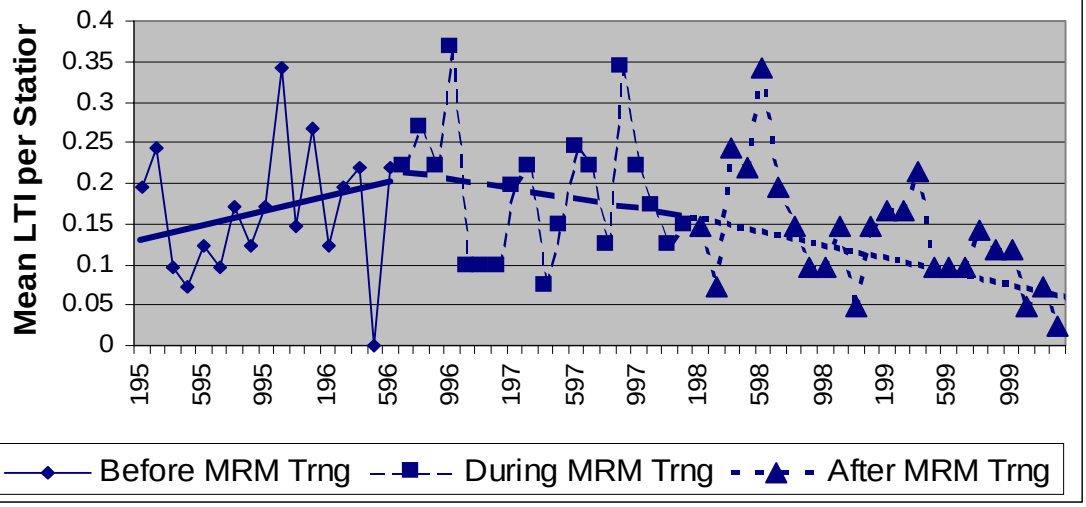
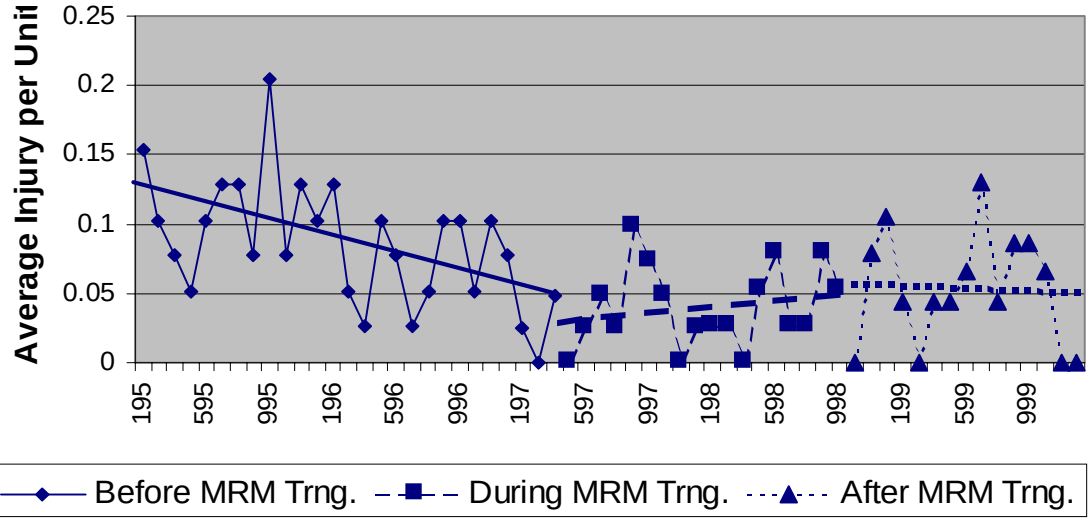


FIGURE 2
Five Years of Line Mtc. Lost Time Injuries
(n=42 stations)



It is clear from the trends in Figures 1 and 2 that a dramatic improvement took place for the line stations taken together. Furthermore, this improvement directly after the onset of the MRM program and its rate of change continues in the two years following the completion of the MRM training. This strongly suggests that the "awareness" program works through its effect on stress management and situation awareness – at least in this company's line maintenance organization.

FIGURE 3
Five Years of Heavy Mtc Lost Time Injuries
(n=40 units)



For the Base Maintenance organization the effects are also encouraging. Figure 3 shows that the trend for lost time injuries remains low during the period of MRM training and that it rises and falls only gradually in the 15 months after the training was concluded. However, because of the sharply downward trend before the training began we must question whether the lower rates during training and after are a continuation of some previous program to lessen injuries in the hangars or they are the result of the MRM training.

An unplanned liability of the individual change model. It is ironic -- given the apparent success of this MRM program as expressed in long-term safety outcomes – that AMTs' enthusiasm for the program turned from positive to negative. Earlier reports examining the attitudes and opinions of line maintenance employees in the months following their MRM training have described the apparent frustration and anger these individuals voiced (Taylor, 1998a). They expected more support by their managers and co-workers in fulfilling the promise of the MRM program to improve communication and collaboration (Taylor, 1998b). Subsequent interviews and observations in the company's repair hangars confirm this "backlash" exists in heavy maintenance as well. AMTs and inspectors reported discouragement waiting for some management safety initiative that was based on the content of the MRM course.

This individual-based awareness training, with its emphasis on building individual's coping skills, appears to give AMTs little subsequent information about whether or how much the MRM program is working, or whether other people value the lessons of the training like they themselves do. Months after the training many AMTs reported still being careful, fighting complacency, and managing their own stress levels. But many also didn't think the MRM program would be very useful in the future (Taylor & Christensen, 1998, pp. 152-160). Many said they didn't know or couldn't tell if others were using the lessons learned from the training – they rarely talked about MRM informally and were never encouraged to do so by their leaders.

Case 6: Distributing 3rd generation MRM training.

One adaptation to the MRM third generation has been to divide two days of training over several months. A large U.S. airline created its own MRM training after reviewing the HPIM training model. The AMT's union and the company's management cooperated to initiate and design the training. Training materials were inspired by the HPIM package, but the most of the exercises and cases were created specifically for this application.

Program purpose. To provide participants with specific human factors principles and techniques to help them work more safely. The definition of MRM, stated in the participant's workbook, "…is the process where we work together, using available resources, to reduce errors and to promote safety." The statement goes on to say, "MRM addresses human factor errors and problem resolution through open and honest communication between all maintenance operations personnel, and with the FAA."

The training topics for the first day are:

- Identify human factors elements
- Recognize the "dirty dozen" error causes

- Identify the chain of events in accidents
- Effective written communication
- Identify norms
- Establish safety nets
- Recognize safety mechanisms

Although the MRM definition quoted above is more active and interpersonal than is typical for the HPIM (3rd generation) model, the supporting topics are largely "awareness" or conceptual issues --with "written communication" as the "active skill" exception.

At the beginning of the second (Phase 2) training day the definition of MRM is reiterated. The training topics in the participants' workbook for the second day are as follows:

- Recognize the nature of errors and how the affect participants
- Focus on how to manage errors
  - "dirty dozen" topics, "lack of assertiveness" and "lack of awareness" are emphasized
- Introduce tools to use in error reduction
  - emphasis on situation awareness

Likewise these topic labels for phase 2 training seem more conceptual than behavioral. The module on lack of assertiveness is, however, focussing on active communication. On the other hand, the main "tool" in the final phase 2 topic list, situation awareness, is an individual, passive mechanism. This MRM program appears to be bridging between the 3rd generation model of individual AMTs coping with safety hazards and issues and the interpersonal communication techniques of the original maintenance safety training.

By design, phase 2 (the second day of training) is conducted about two months after the first one.

The course is designed for all maintenance employees and each session is expected to include management and hourly employees from a variety of functions within maintenance. Initially, the training took place in a large line station and both phases 1 and 2 were completed there before the program was moved to two cities containing both base and line maintenance stations. Eventually all 8,000 maintenance employees throughout the system are expected to attend the training.

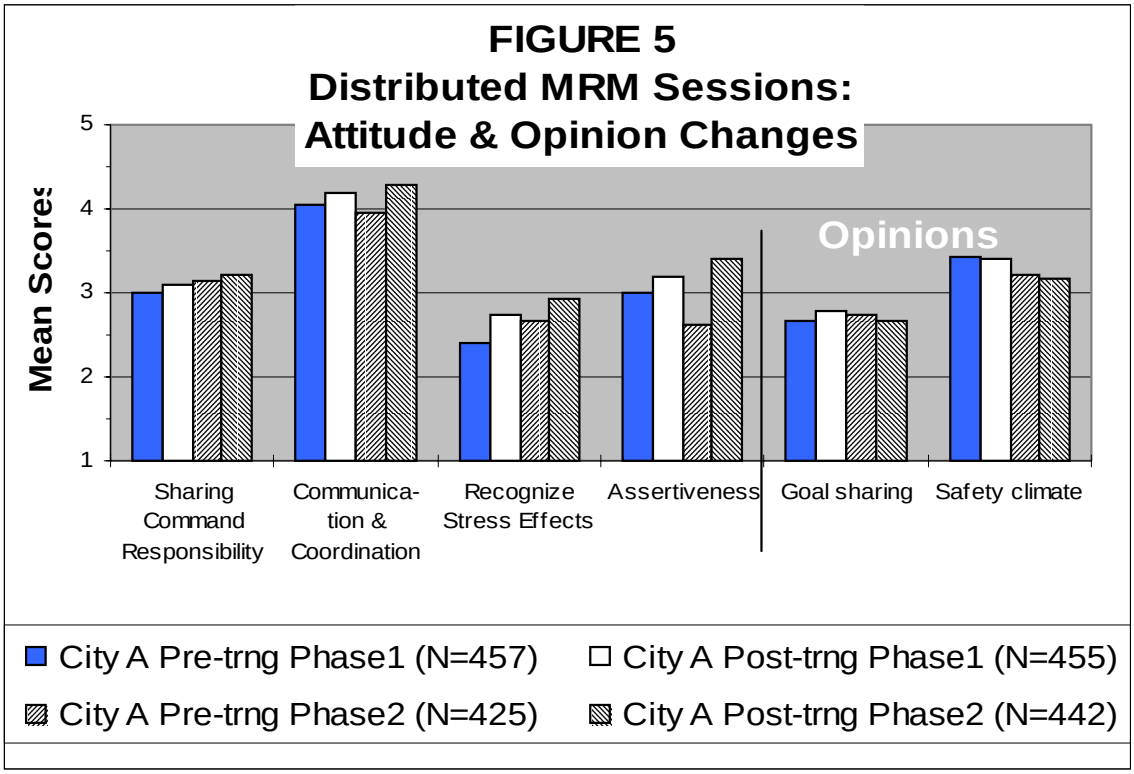
Phase 1 training for the first city (line maintenance station "A") was 85 percent completed between January and March 1998 and the remainder (for a total of some 500 maintenance employees) was finished in July. Phase 2 was completed during August and September 1998. The second city ("B") to begin the MRM training included both a large line station and a major heavy maintenance base. City B began phase 1 training in September1998 and completed it with about 1,000 maintenance personnel in April 1999. Phase 2 began in city B during June 1999 and was about 50 percent completed by December 1999. A third city (also both a large line station and a major heavy maintenance base) began phase 1 training in July 1999 and, with over 900 employees attending, had not yet been completed by December 1999. Results from cities A and B

will be used below to illustrate the effects of distributed training and the modified course purpose and topics.

Likelihood of voluntary change. Enthusiasm for city A is moderate when compared with past MRM experience described for the cases above. Slightly over 60% of the participants following phase 1 said there would be a moderate to large change in their on-the-job behavior. Following phase 2, 65% city A participants said there would at least a moderate increase in their at-work activities. This modest increase in encouraging, but statistical tests of this result; or the that between the associated phase 1 and 2 mean scores, do not show significant differences. For city B the enthusiasm following phase 1 is also moderate with some 69% saying there would at least a moderate change in their behavior. Following phase 2, 85% in city B say they expect moderate to large change in their at-work activities. With only half of the phase 1 respondents having attended phase 2 training these results are incomplete, but they are certainly promising.

Attitude changes. Figure 5 shows the mean scores for attitudes and opinions for city "A," the first station to complete the two phase MRM program. Immediately following the Phase 1 training, participants' attitudes reveal significant improvement in attitudes toward communication, stress management and assertiveness. Following Phase two training all three attitudes increased again significantly. Although attitudes toward sharing command responsibility increase slightly over this time, the differences are not statistically significant.

FIGURE 5
Distributed MRM Sessions:
Attitude & Opinion Changes



Opinion changes. Figure 5 also shows city A participants' evaluation of their station's goal setting and sharing remained unchanged between phases 1 and 2. However their evaluations of the station's safety climate decreased significantly ($F=8.29$, $p<.001$) between phases 1 and 2. Field observation at city A some 60 days after phase 1 training

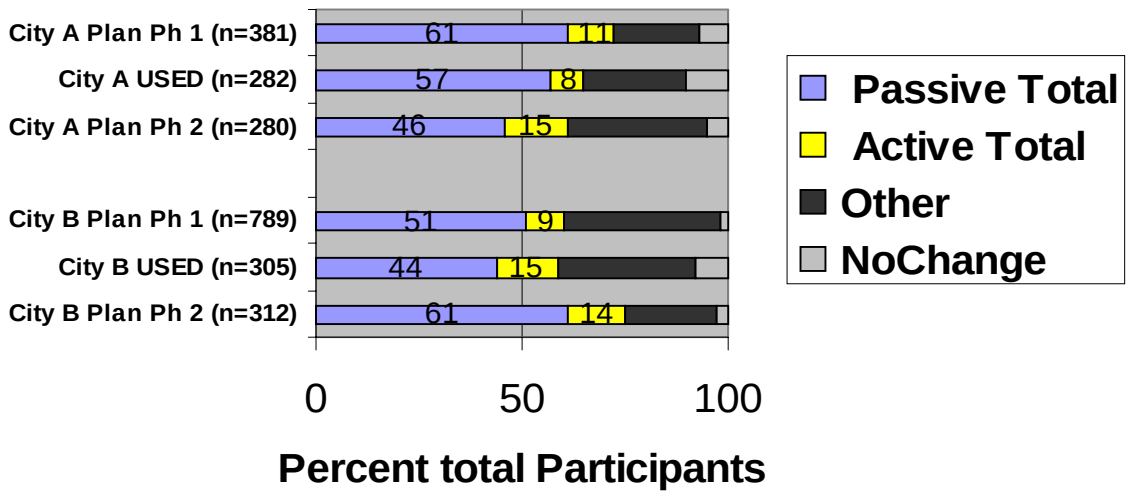
and again four months after phase 2 confirm these survey results. AMTs, leads, and foremen reported that safety standards and program seemed to be deteriorating. Apart from their own individual care and awareness, they said, little was being done to support maintenance safety in the station.

Specific intentions to change. The question, "how will you use this training on the job?" was included in the surveys that followed both phase 1 and phase 2 training. City A participants' answers to that question were coded for intentions to begin active communication with management and coworkers, as well as for intentions to apply more individual, passive, coping behaviors. If respondents said they weren't intending to change at all, that was coded separately. Those answers that didn't fit any of the categories were coded "other." Answers to the same question from city B's MRM participants were similarly coded and can be compared with city A's results.

Self-reported changes between MRM phases 1 and 2. The post-phase 2 survey asked the question, "how have you used the MRM training on your job?" The answers received were coded the same as those for the question of intention. Thus both intention to change and the subsequent changes can be compared over time. These data are presently available for city A in its entirety as well as for first half of the city B participants who have completed phase 2 training.

Figure 6 presents the expected behaviors at the end of both phase 1 and 2 training. The figure also shows the actual behaviors reported by participants at the time of the phase 2 training. Although 11 percent in city A said they intended to communicate actively following phase 1, only eight percent reported having done so when they returned for phase 2 training.

FIGURE 6
Planning for, and using the MRM training

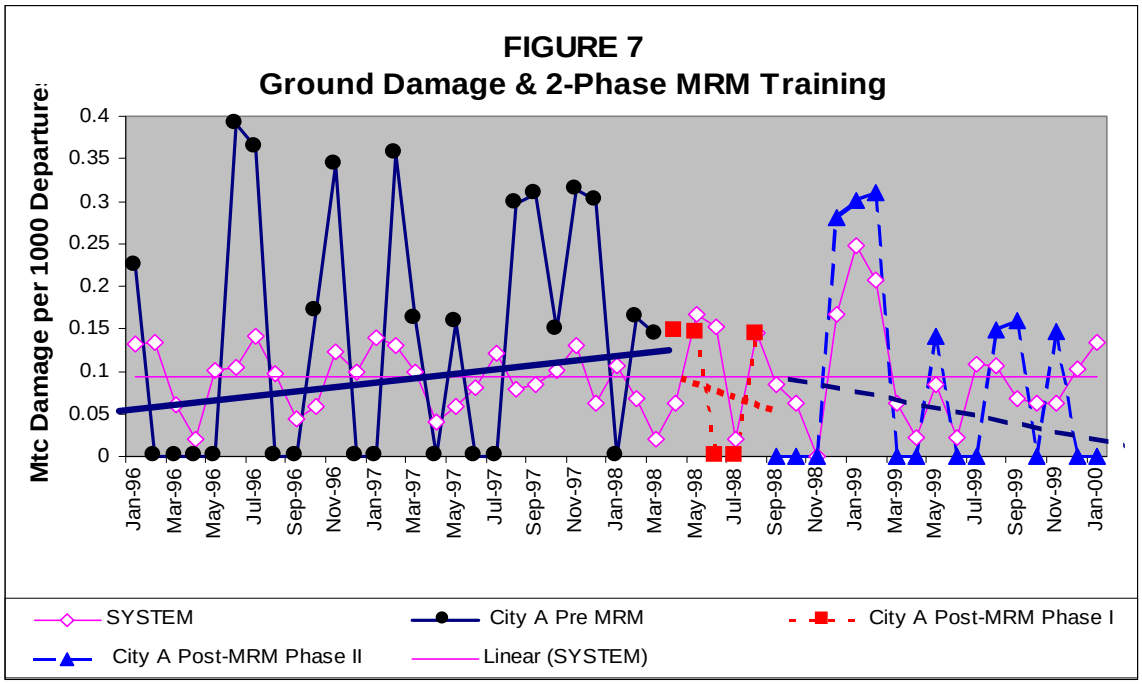


Fifteen percent expected to actively communicate after attending the second day. For city B a larger percentage (nearly twice as large as city A) reported having been more

active communicators when they returned for phase 2, and that proportion again, further expected to actively communicate with others about safety. These results, even though they shift slightly more toward active intentions following phase 2 training they do not favorably compare with the proportions of active to passive intentions found in cases in the first generation of MRM training. This ratio in figure 6 (generally about 15 percent active to over 45 percent passive) is much less than the 40 percent active to 45 percent passive intentions in the earlier programs (Taylor & Robertson, 1995; Taylor, et al., 1997)).

Performance changes. Four years (1996-99) of aircraft damage incidents charged to city A maintenance are compared with all line stations in Figure 7. The overall pattern of ground damage incidents for all (n=45) line stations in the system remains steady with a flat trend line during this four year period. The results for city A, however, show an increasing incident rate before the MRM training began. That trend reverses following the phase 1 training and it continues downward for 16 months after the second training phase concluded. The initial ground damage results for city B are not portrayed here, but they track a similar pattern of increasing incidents before the onset of the MRM training followed by a marked decline after the program begins.

FIGURE 7
Ground Damage & 2-Phase MRM Training



This improvement in safety results is further evidence for the effect that MRM awareness instruction can have on maintenance performance. This, coupled with sustained enthusiasm following more than a year from the completion of the training suggests that the distributed, two-phase training program may avoid some of the frustration and anger caused by a perceived lack of support by their managers and co-workers to improve the safety climate (Taylor, 1998b).

This two-phase MRM training appears to provide several additional advantages over the one-shot training model.

- First, it provides the opportunity for program facilitators to follow-up and elaborate the lessons from the first session. For example, some changes to the phase 2 curriculum for city B were made after the program had been used at city A.
- Second, the subsequent session begins to demonstrate management's commitment to an ongoing MRM program. Unlike the experience in case 5 above, where interest in changing behavior declines steadily in the months after training, some enthusiasm for the program in the present case continues months after the initial training.
- Third, it should satisfy those participants who want recurrent training on these topics. Typically some 10 to 12 % of participants in previous MRM programs have said that recurrent MRM training would make an improvement to the one-shot model. In this case however the expectation for further MRM training may be heightened with a two-phase program. In this regard nearly 20% of the participants' following the case 6 two-phased training said even further recurrent training would improve this model. Another 20% are eager to see more management and employees from other maintenance groups experience this MRM training.

Despite the successes reported for cases 5 and 6, together with the added advantages of the distributed awareness training, they remain programs to influence the values and awareness of individuals. These programs do not create the structure and the process for improving safety at a systemic, interpersonal level. They also do not have clear safety goals, rapid feedback of results, and appropriate reinforcement for those who are behaving more safely. Without these systemic, organizational features, MRM programs like those illustrated in cases 5 and 6 seem destined to suffer the irony of increased long term improvement coupled with participants' ignorance about that gain and greater pessimism about the quality of maintenance safety programs. The sheer professionalism of the AMTs themselves makes these present programs work. AMTs are reminded of the dangers of the "dirty dozen" causes of errors and accidents and they respond appropriately – on their own and apparently for a period of months, or years not weeks.

Generation 4: Integrated, behavior-based MRM programs.

The fourth generation MRM programs are using the knowledge gained from the experience of the past three generations and from recent innovative processes to standardize communication and tactical decision making. For the first time, these programs are being designed and implemented from a systemic perspective. Data from the past three generations of MRM programs shows that different MRM programs usually achieve different results. Therefore, airlines are now adding a skills training module to their classroom instruction and making it a true "training" program that is more likely to result in more open communication (Patankar & Taylor, in press). These airlines are also aware of the interpersonal trust issues that impede self-disclosure, and they are striving to incorporate a maintenance error investigation (MEI) module in their training, and in their larger program, so that the participants understand the goal and the procedure of such investigation. In the skills training module, the airlines are beginning to train their maintenance personnel to use simple, standard processes to detect and resolve differences in information through third-party validation. The airlines are now better informed about the capabilities and limitations of MRM programs, and they are

embarking on a new result-oriented approach to safety through strategic, system-wide, changes.

Understanding the human factor in unanticipated events. Real time knowledge of what human factors lie behind classes of maintenance errors is important to obtain, and central to the long-range and comprehensive success of MRM. Processes for a human-centered maintenance error investigation (MEI) are becoming objects of serious interests in aviation maintenance organization (Allen & Marx, 1994; FAA, 1999). However, full-blown maintenance experience with such programs is limited. A recent expert assessment of MEI in the U.S. shows that there has been little commitment yet by either the air carriers or repair stations to see such error investigation and analysis become a new way of doing business (Marx, 1998).

Trust within the maintenance system. Informal reports from users suggest that AMTs limited trust of the MEI process creates an obstacle to its widespread diffusion. Why should an AMT cooperate with management in investigating his/her own mistakes? Unless a strong culture for open communication and assertiveness already exists in their organization, relatively few AMTs will voluntarily or willingly disclose what they believe to be the "real story." AMTs' individualism (Taylor, 1999; Taylor & Patankar, 1999) and self-reliance (Taylor & Christensen, 1998) can limit their trust in others.

In order to develop a strong safety culture a maintenance organization must first recognize its own organizational and occupational culture, and it must appreciate the interplay between these two with the effects of national origins and cultures of its individual members (Taylor, 1999; Patankar, 1999).

Now, at the beginning of the 21st Century, MRM is being seen as more than mere "awareness training," or coping skills for individual AMTs – it is the conscious process of increasing trust among maintainers, their managers, and their regulators that enable them to learn from present behaviors in order to improve future quality and efficiency. MRM is now a process of cultural change.

Direct focus on behavior change.

The focus of contemporary MRM programs is now moving toward active error reduction through structured communication. Patankar and Taylor (1999) describe a case from the corporate aviation environment that uses a "behavior-change first" approach instead of the prevalent "attitude-change first" of MRM. In the earlier MRM generations 1 and 3, companies simply provided classroom instruction and hoped that the desired change in attitudes and behavior would take place automatically. This strategy focused on changing the participants' attitude toward safety through education and persuasion, and sometimes skill training. Its developers hoped that participants' behavior would change as a consequence of the classroom experience alone. Unfortunately, the evaluations of such "training" programs for improving communication revealed that the subsequent behavior change is limited – either in scope or duration.

At the same time there were companies that began to provide a simple structure and process for communication among all departments associated with aviation operations: flight crew, maintenance, and administration. These companies assumed that if they provided a simple, consistent communication and decision making process, and the outcome of this

process was promptly acted upon and continuously supported, their employees would continue to use it and could eventually change their attitudes. The immediate interest of these companies was in changing their employees' work-related communication behavior, they did not use the better known "attitude change" approach taken in MRM generations 1 and 2.

The Structured Communication Process.

Basically, there are two aspects to achieving new communication behavior: first, a structure which requires connected parties to communicate, and second, a process that is followed consistently—regardless of the outcome.

Structure: An example of structure might be an organization policy for line maintenance which requires that for each flight an AMT act (either by direction or discretion) as its liaison AMT. This person is expected to meet with the flight crew and discuss the maintenance issues with them. The pilots are expected to remain after arrival to discuss maintenance discrepancies with the AMT. During such discussions, both the flight crew and the maintenance AMT(s) are required to follow the pre-agreed communication process described below. Another example of structure is a policy requiring that maintenance shift turnovers take place face-to-face; and that among other standing agenda items is the expectation that AMTs leads and foremen briefly review the outgoing shift's use of the pre-agreed decision making process.

Process: The process for enhanced aviation communication has been observed and documented (Lynch, 1996; Patankar & Taylor, 1999). Its originators have titled it the Concept Alignment Process, or "CAP." According to this process, a "concept" is an idea or a piece of information presented by an observer of, of a party to a technical decision. All members are expected to present their concepts. If the members present differing concepts, they must validate their concepts from a third party source such as a flight manual, air traffic controller, maintenance manual, company policy, etc. If only one concept can be validated, it is executed; if none of the concepts can be validated, the most conservative concept is executed; and if multiple concepts can be validated, the senior ranking person has the authority to choose any one of the valid concepts. Additionally, when multiple concepts are stated, whether valid or not, the members are required to investigate the reasons for the existence of multiple concepts. Such an investigation is aimed at providing systemic feedback to minimize the occurrence of multiple concepts, at least not the non-validated ones.

The Concept Alignment Process addresses the following causes of human error accidents (Lynch, 1996):

- Nonadherence to procedure
- Incorrect tactical decisions
- Inattention or complacency
- Failure to challenge another member's error

The CAP provides objective procedures, thus making the use of the process observable to all. It provides team members with decision-making and conflict resolution methodology. It reduces chances of acting on incorrect concepts for forcing collaborative task completion and decision making. It reduces interpersonal conflict and defensiveness through the understanding that what is challenged is the concept and not the individual.

All of these benefits have been observed in the use of CAP in the maintenance environment. The following description of Case 7 highlights those benefits.

Case 7: Concept Alignment Process to facilitate crew communication and consistent decision-making among all members of a corporate aviation department.

The aviation department of a large U.S. corporation trained all of its flight crew and maintenance members to use this system and the management used it as well.

Purpose: The CAP, a communication and decision-making protocol, was implemented to enhance systemic safety through early identification and management of risk. With this approach, management intended to impact behavior and did not aim to directly or immediately change attitudes toward interpersonal relations at work.

The management required that all aviation employees use CAP actively and held them accountable for it. Therefore, the use of the system was not voluntary. This is consistent with the behavior-first strategy discussed earlier. However, Patankar and Taylor (1999) observed that once the employees (both flight and maintenance crew members) experienced successful implementation of the process and consistent support from the management, even if it meant making policy changes or confronting the local FAA, their belief in the process grew and their attitude toward safety and toward the use of this process changed over time. Most maintenance employees agreed that it took some time for them to really understand the process and be able to apply it consistently. The flight operations personnel had been using CAP for almost three years before the maintenance manager began learning the process. He customized the original flight-oriented program to a maintenance-oriented program and called it "Error Reduction & Decision Making Process."

Likelihood of voluntary change. A year after the Maintenance Error Reduction Program began; AMTs were surveyed for their attitudes and opinions about it. Only 40% of the AMTs said the program had at least moderate effect on their behavior, but nearly three-quarters of them reported that the program had been useful to others. Regardless of how they may discount the program's effects on themselves, these AMTs could see the effects on the others around them.

Attitude and opinions. Compared with our standard dataset (Taylor, in press), the survey for this aviation department showed favorable attitudes toward sharing command responsibility, and for assertiveness. These people do value speaking up and making decisions. Their attitudes toward communication however, were substantially below our standard benchmark. That is, they appear not to value or enjoy communication for it's own sake. Their assessment of goal setting and sharing is at the benchmark norm, while their evaluation of the department's safety climate was higher than the norm.

Behavior changes: The behavior changes were almost immediate. Because the change was mandatory and the employees were evaluated based on their ability to use the process, everyone tried to use it. Although some did not believe in it as much as others did, they all used it. There were a few product champions who consistently used the CAP process and more assertively addressed the concepts of others. Self-reports of how the process was used and stated intentions to continue using it are encouraging. Two-thirds of the AMTs reported that the program caused them to communicate actively while only one member described behaving passively as a result of the CAP process. Reported intentions to further use the

process were weighted toward active communication vs. passive reaction in a ratio of two to one.

As the AMTs observed that the management supported the process, regardless of the outcome, they started to trust this new communication protocol and continued to use it. There were times when the flight crew and the maintenance crew had disagreements and each party was able to validate its concept (Patankar & Taylor, 1999). Under such circumstances, the department manager was able to step-in, validate the application of the process, and determine an outcome that was consistent with the CAP protocol. Consequently, all parties emerged trusting the process more.

Performance changes: As a result of the CAP process, the maintenance personnel, the flight crew, and the management were more actively engaging external vendors, aircraft manufacturers, and their local FAA for more accurate and acceptable solutions to problems. Additionally, the maintenance manager was able to follow-up on several information discrepancies, determine their root cause, and make the necessary structural or procedural changes so that the same discrepancy would not arise in the future.

Processes such as CAP focus on behavioral outcomes rather than attitudinal change by providing a simple structure and process for communication among all parties involved in aircraft operations. The consistent use of this pre-agreed process, regardless of the outcome, in genuine pursuit of systemic improvements toward safety builds trust among all parties. Through consistent use of this process, the corporate aviation department was able to raise the performance standards at an individual as well as organizational level. Such an approach shows strong potential for long-term changes in the aviation safety culture.

Organizational safety culture and management support.

Assuming that organizational culture has "the potential for the greatest impact on safety," Merritt and Helmreich (1996, p.21) present strategies to unify and strengthen the organizational culture and aim to introduce safety as a shared value. Management's commitment, Merritt and Helmreich suggest, is prerequisite to successful implementation of new process or protocol because although an organizational culture is shaped by all of the employees, an organizational change is defined by the upper management. The change has to be top-down, through concrete and consistent examples.

In case 7, the CAP communication protocol worked as an outstanding strategy to unify and strengthen the organizational culture because the top management agreed to manage risk through team decision making. On the flight side, the pilots were required to conduct preflight briefings and post-flight debriefings for every flight. Similarly, in the maintenance department, the AMTs were required to conduct regular briefings with the flight crew and follow the approved protocol. In addition maintenance personnel agreed to discuss the recent use of CAP during their daily shift turnover meetings. The management fully supported these briefings and meetings by agreeing to act on the subsequent recommendations in a timely manner.

By visibly supporting these activities, the management created an environment which expected everyone to follow the CAP protocol in making decisions and that all the employees base these decisions on safety concerns as well as on scheduling. Every

employee does not need to believe in this communication process, but they are required to practice it. Awards and penalties are based on the employee's ability to follow the process. With a demonstrated consistent support to the process, regardless of the resulting recommendations, the employees gain confidence and build safety as a shared value.

Case 8: MRM combining direct behavior change with awareness instruction and error investigation.

A large airline has recently designed an MRM program based on the best practices from the industry, together with innovative ways of adapting those practices to their own company culture.

Program purpose. To expand the view of MRM providing participants with awareness of human factors principles, to include skills training and techniques to help identify and correct mistakes, oversights, and lack of knowledge. "Dirty dozen" issues initially emphasized are lack of communication, lack of knowledge, and lack of teamwork.

The MRM program topics are:

- Training for awareness and basic safety skills
- Incident/error investigation
- Resolving differences in knowledge and information for improved decision making
- Baseline metrics for trust, for errors and incidents, and for attitudes toward safety and teamwork

A one-day training session is planned for employees and managers in all maintenance locations and functions. The syllabus is based on the topics above, and contains the following six 45-minute modules.

1. Introduction to human factors concepts
   - As cause of accidents
   - Human-machine interface
   - MRM as training plus skills and support
   - Local maintenance case video
2. The Dirty Dozen
3. Maintenance errors
   - Mistakes and violations: local case illustration
   - Concept Alignment Process (CAP): Catch them before they happen
4. Ways to eliminate errors
   - Culture change
   - Trust
   - Individual actions
   - CAP resolution: local case illustration
5. The company's MRM program
   - Maintenance Error Investigation (MEI): local case illustration
   - What to do if you catch yourself in an error? (ASRS)

Setting our goals and celebrating our achievements

6. Where to get more information
   FAA website
   ASRS/NASA
   Company MRM department

Maintenance error investigation (MEI) process. The company does not currently have either a standardized information gathering process for MX errors and incidents. As part of their MRM program they expect to provide maintenance leads and managers with a standardized process to follow in error investigation, which will provide a means to gather information about errors and how they occur. It will help determine where to concentrate efforts for error reduction and prevention in the rest of the MRM program. And it will reduce fear of unknown for those that may have committed errors.

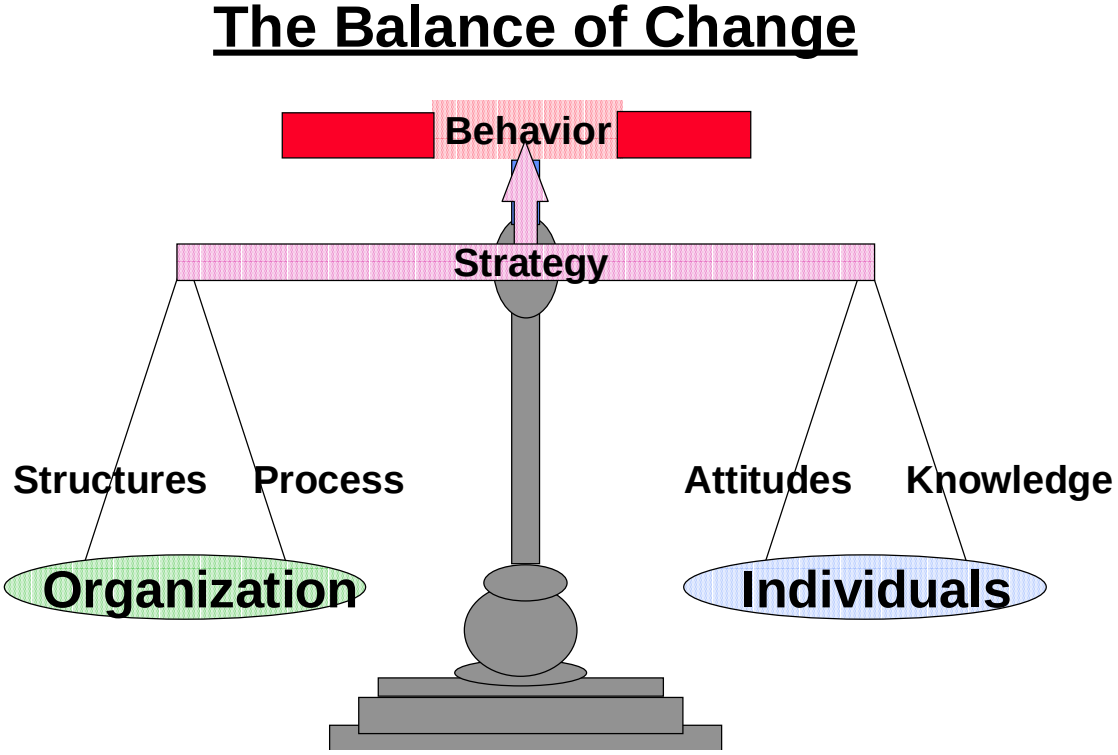
They expect to complete implementation of the awareness and skills training before implementing their MEI process. Currently they expect to obtain more training in MEI methods and to prepare an "ASAP" memo of understanding (FAA, 1999). They will develop a process that will work best for them.

Their MRM program will contain much of the best of MRM development over the past decade --it is designed to be systemic, integrated, data-based. Their experience with the process and its outcomes will be monitored and assessed.

The Balance of Change

Based on the experience of the first three generations of MRM programs, the fourth generation programs, such as the one described in case 8, are starting to address the issue of balance among individual and organizational changes. In theory, both the individual and the organization must change in order to effect a long-term change in the safety culture. The first generation MRM program customized the concepts from CRM training to maintenance by focusing on teamwork—communication between two or more individuals – but it was still personal change and little attempt to support it through organizational structure or process was made. The second generation MRM programs used focus groups to solve specific problems resulting in some organizational changes and some individual changes, but because these programs were focused at specific problems, once problems were solved and to continue the process proved difficult, the programs were discontinued. The third generation MRM programs focused on individual awareness resulting in mostly passive individual change.

Now, as illustrated in the figure below, the balance of organizational change (e.g., cases 4 and 7) together with individual change (cases 2,3,5 and 6) is becoming an idea "in good currency." This balance provides structure and processes for individuals to practice the desired behaviors, as well as the encouragement and personal support for individuals taking a positive attitude about safety, as well as knowledge and skills for how to do it. Strategy or purpose guides the balance. If either the organization or the individual does not perform the requisite function, the resultant behavior will be unbalanced and not achieve the higher levels that are possible through planning (Taylor & Patankar, in press).



CONCLUSION

Awareness programs as illustrated in cases 5 and 6 raised the safety consciousness among maintenance personnel and improved their attitude toward safe practices. And these programs achieved considerable success in causing individual changes in coping with safety hazards. However in these most recent programs there has been little change in communication. In cases 2 and 3, where open and assertive communication was improved through training the positive results were not sustained. The behavior-based programs, such as illustrated by cases 4 and 7 focused on promoting the desired behavior rather than changing attitudes toward safety. Consequently, the behavior-based programs achieved a more readily observable change in behavior. This body of research has illustrated the ability of MRM programs to influence several different areas ranging from injuries and aircraft damage, to paperwork error reduction. The fourth generation of MRM programs appears to be based upon improving on these successes as it moves toward an integrated, behavior-based philosophy. Programs in this 4th generation, such as that described in case 8, can be expected to effect significant improvements in aviation safety. The forth generation MRM programs will be among the first to truly satisfy the "interactive" part of the 1999 ATA definition of MRM programs. But this success will depend on developing a process that builds interpersonal trust—assuring the AMTs that they will be treated fairly—because the AMTs will have to be actively involved in

identifying individual and organizational errors to accomplish the next higher level of aviation safety.

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